Frontier research

Advanced ICT Research Institute

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The Advanced ICT Research Institute is engaged in research and development toward innovative information and communications technology (ICT) for future society, that cannot be achieved by improving existing technologies. To achieve this, we are exploring to create new concepts, new technologies, and new materials that can produce fundamental technologies for ICT in the future. Specific technologies targeted for R&D include high-functionality ICT device technology explore the epoch-making fundamental technology as the core of various ICT devices by developing and creating high-functional elements and groundbreaking fabrication technologies with extreme precision, quantum ICT technologies to create reliable and robust communication technologies based on the ultimate scientific principle of quantum mechanics, ultra-high-frequency terahertz (THz) technologies toward pioneer ultra-high-speed wireless communications and sensing technologies that surpass existing technologies, and fundamental Bio-ICT technologies to produce new ICT paradigm by investigating and applying the superior functions and efficient mechanisms of living things. And besides, to promote the social adoption of the results produced by these basic and fundamental research projects, we have established three technology development centers in the institute: Quantum ICT Advanced Development Center, Green ICT Device Advanced Development Center, and DUV ICT Device Advanced Development Center, focusing our research and development efforts on near-future implementation of our research establishments from a needs-oriented point of view.

The following introduces major research results to date.

High-functionality ICT device technology

In our research on small, ultra-fast optical modulators for practical use, we succeeded in filling a silicon slot waveguide with an organic electro-optic (EO) polymer with no voids with the aim of achieving 400-Gbps-plus optical interconnects. We also verified the optical-propagation properties of this waveguide thereby obtaining technology that can achieve hybrid optical modulators based on an organic-EO-polymer/Si-slot waveguide. Furthermore, in ever-expanding interdisciplinary research toward THz-class ultra-high-frequency applications, we succeeded in fabricating an organic-EO-polymer ridge waveguide clad in THz low-absorption material and verified high-efficiency THz-wave generation by a novel waveguide structure the first of its kind in the world (Fig.1).

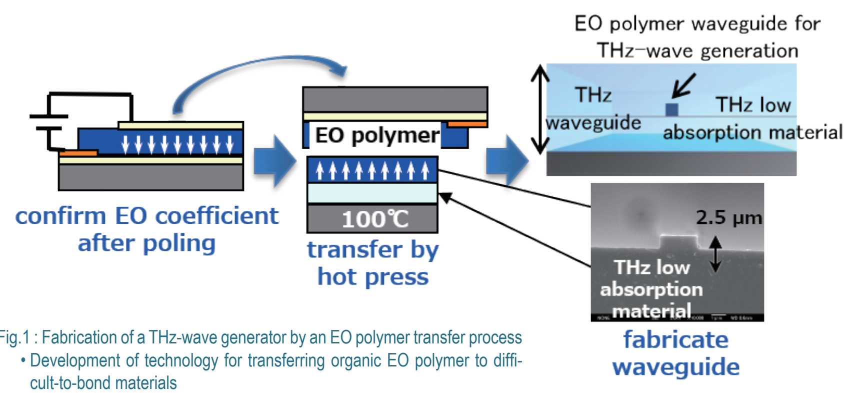

Fig.1 : Fabrication of a THz-wave generator by an EO polymer transfer process
• Development of technology for transferring organic EO polymer to difficult-to-bond materials
• World's first THz-wave high-efficiency generator from a ridge waveguide

Next, in our R&D efforts aimed at broadening the application field of superconducting single photon detectors (SSPDs), we demonstrated high-speed response seven times that of our conventional SSPDs in a new device structure called the superconducting nanowire avalanche photodetector (SNAP). We fabricated a multi-pixel (32×32) SSPD prototype and developed cryogenic signal processing using a single-flux-quantum (SFQ) circuit operating with a time accuracy below 10 ps for a high-speed SSPD system. In the development of feromagnetic Josephson junctions for application to superconducting qubits, we succeeded in observing the π state for the first time in the world in a magnetic Josephson junction made of a nitride superconductor (Fig.2), which is an important fundamental technology for realizing superconducting qubits with superior coherence.

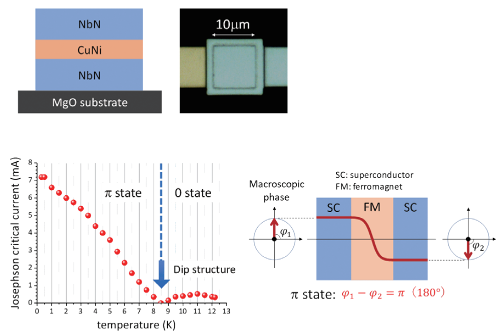

Fig.2 : Upper: Device structure and micrograph of magnetic Josephson junction
Lower: Temperature dependence of Josephson critical current and observation of π state

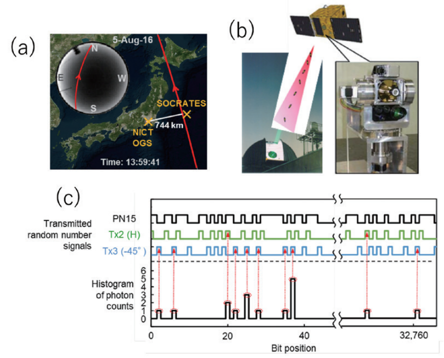

Fig.3 : Upper left: NICT optical ground station (OGS) and microsatellite (SOCRATES) orbit (red line)
Upper right: Photo of satellite, OGS, and SOTA
Bottom: Transmitted random-sequence signal and received signal at OGS

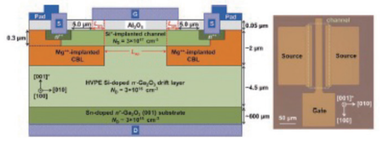

Fig.4 : Cross sectional diagram (left) and optical micrograph (right) of vertical D-mode Ga_2O_3 MOSFET

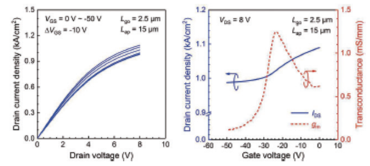

Fig.5 : DC current versus voltage output characteristics (left) and transfer characteristics (right) of vertical D-mode Ga_2O_3 MOSFET

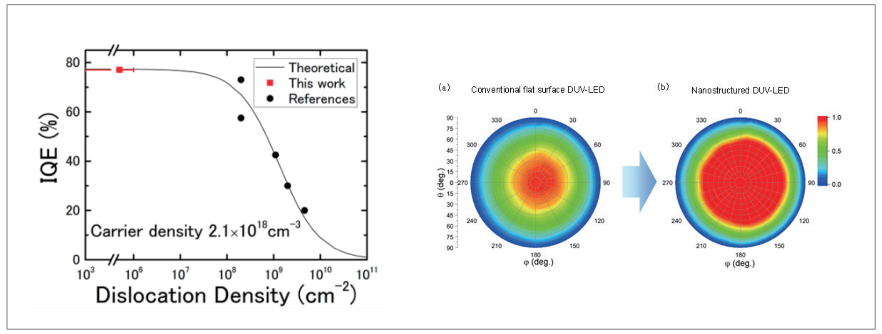

Fig.6 : Internal quantum efficiencies (left) and 3D far-field radiation patterns (right) of DUV-LEDs

High-frequency terahertz fundamental technologies

We achieved a 300-GHz silicon-CMOS receiver integrated circuit and combined it with a transmitter circuit implemented in FY2016. In this way, we achieved 300-GHz operation for both transmission and reception on a silicon integrated circuit. This achievement won a best-paper award for the second time at the IEEE International Symposium on Radio-Frequency Integration Technology (RFIT, August 2017) following an award received in FY2015.

BioICT fundamental technologies

We succeeded in producing new molecular devices having promising functions by combining biological molecular modules existing in nature. In this way, we have obtained a foothold toward achieving biomimetic devices having some of the superior features of living things. This achievement appeared in the Current Opinion in Biotechnology journal highlighted on its cover page.

Quantum cryptography and physical-layer security technology

Taking photon-signal discrimination technology developed as a quantum technology for free-space transmission, we applied it to a quantum-communication receiver for satellite/ground-station free-space optical communications using a Small Optical TrAnsponder (SOTA) mounted on a 50-kg-class microsatellite (SOCRATES) and performed a basic quantum-communication experiment. The Space Communications Laboratory of the Wireless Networks Research Center at NICT developed this SOTA terminal. In this experiment, we succeeded in receiving very weak signals with an average of 0.14 photons/pulse from this microsatellite at a ground station and performed time synchronization, polarization axis alignment, and photon-stream bit-pattern decoding against these signals (Fig.3). This was the world's first experimental demonstration of quantum communication using a microsatellite.

Quantum node technology

In the field of quantum metrology, we developed a new indium-ion cooling method (joint cooling) and improved the accuracy of indium-ion optical frequency standards by 1/10 compared with the current worldwide maximum value in collaboration with the Space-Time Standards Laboratory of the Applied Electromagnetic Research Institute at NICT.

Development of a vertical Ga_2O_3 transistor

We fabricated a prototype version of a vertical depletion mode (D-mode) Ga_2O_3 metal-oxide-semiconductor field-effect transistor (MOSFET) and evaluated device characteristics. Figure 4 shows a cross sectional diagram and an optical micrograph of a vertical D-mode Ga_2O_3 MOSFET fabricated in FY2017. Figure 5 shows DC current versus voltage output characteristics and transfer characteristics of this device. With this prototype, we achieved the world's first operation demonstration of a genuine vertical Ga_2O_3 transistor.

DUV optical device technology

We have developed a new method to determine the internal quantum efficiency and current injection efficiency of deep ultraviolet (DUV) light-emitting diodes (LEDs) during current injection. As a result, we have demonstrated, for the first time, an extremely high value of 77% for internal quantum efficiency in a DUV-LED during current injection (Fig.6, left). This result was published in Optics Express as a highlighted paper representing an outstanding achievement of excellent scientific quality in this field. We also greatly improved light-extraction characteristics and droop characteristics using DUV-LEDs incorporating newly developed aluminum-nitride (AlN) nanophotonic/nanofin structures (Fig.6, right), and successfully demonstrated the world's highest continuous-wave output power in excess of 200 mW in a single-chip DUV-LED at a peak emission wavelength of 265 nm.